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Analysis of the characteristics of the tomato manufacturing residues finalized to the energy recovery

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ABSTRACT

Tomato manufacturing industry originates substantial amounts of residues. If left without control these residues can constitute an environmental problem. Their energetic use can solve this problem and give added value to the process. In this research physical-chemical characteristics of this biomass and its components are studied to evaluate the possibility of an energy recovery. In general, the dry residues of tomato processing industry are suitable as solid biofuel for energy purposes in large size power plants. The separation of components that constitute tomato residues (peels and seeds) makes sense in case of production and exploitation of oil from tomato seeds. The results can be useful for developing standards on these materials.

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1. Introduction

Food industries generate substantial quantities of residues. When unutilized these residues become wastes that contribute to disposal problems and also aggravate environmental pollution. For instance a storage without control of some residual biomasses could produce methane when undergoing in anaerobic fermentation. Methane has strong greenhouse effect and also affects the formation of tropospheric (ground-level) ozone, which can affect human health, vegetation, and building materials. The product reuse for specific purposes thus produces very positive environmental effects [1].

Among several food industries the tomato paste manufacturing industry is one of the leading ones. This indication is confirmed by the wide diffusion of tomato crop (*Solanum lycopersicum*). In 2006 the global yield was 125 Tg [2]. World

Processing Tomato Council (WPTC) argues that, between 2008 and 2010, Members in Mediterranean Region (AMITOM) have processed about 15.5 Tg of tomato; Italy is one of the main producers and processors of industrial tomato in Europe. Processed tomato was, in 2011, almost 5 Tg (WPTC).

Solid residues derive from both tomato production and process. The discard from production line is due to defects of the incoming raw material, such as immature tomatoes or seriously defective pigmentation, damaged tomatoes for mechanical causes or for microbial action.

On the other hand, also industrial processing of tomatoes generates residues in many ways: from water flumes, washing, sorting table, pulper-refiner (tomato pomace) and cleaning. As mentioned above, residue material can be an added cost for manufacturing companies because of the disposal processes. For this reason residues are currently sold or given

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for free to other companies or removed by specialized firms on payment by the tomato processing companies.

Solid residue mass fraction is about 7.0–7.5% of the total residue mass. Tomato pomace in particular constitutes the major part of the residue mass that comes from the pulper (71–72%) [3,4]. The wet pomace contains the following mass fractions: 33% seed, 27% peel and 40% pulp. The dried pomace contains 44% seed and 56% pulp and peel [5,6]. Tomato seeds can be separated from pulp and peel by a sedimentation system, then dried and used for oil extraction [7].

These residues streams are therefore consistent and could have two prevailing valorizations: the use as raw material for feeding livestock [8] and the direct return in agriculture as soil amendment [9].

Some of the researches focusing on the valorization of residues in tomato industry have shown the possibility to obtain a high amount of valuable chemicals like, for example, phenols, lycopene and ascorbic acid by specific processes [10,11].

A study pointed out that peels and seeds contain essential amino-acids and have, particularly seeds, a high mineral content (iron, manganese, zinc and copper) and mono-unsaturated fatty acids, especially oleic acid [12]. Several authors have highlighted the possibility of using the tomato processing residue, in particular the peels, as a source of carotenoids to be used to enrich other foods and feeds [13–15].

Other authors promote the use of tomato residues to obtain biopolymers that may also be reused in the same industry [16,17] or in different sectors such as agriculture (solarization and mulching) and drug industry.

A further use of this residual biomass is represented by its energetic application, which environmental benefits have been highlighted by many authors [1]. This kind of biomass can be employed in special power stations to produce electricity [18]. Furthermore a study took into consideration the recovery of biogas by controlled anaerobic fermentation of residues [19].

In general, the choice of the best energy recovery and the type of conversion technique depend on chemical and

energetic properties of the biomass. With regard to tomato processing residues the literature does not offer much information. The few available sources claim that these materials exhibit low values of sulfur and ash content and high volatile matter content. A high heating value appears to be related to the oil content in residues [1]. The chlorine and sulfur contents have a great importance when solid biomasses are used for energy production and they are always analyzed with deep attention: these elements in fact can increase the environmental problems [20,21] and the corrosion of thermal plants.

In order to provide a greater number of information on the characteristics of this biomass a wide research has been realized on the energetic properties of those materials applying the CEN/TC 335 analytical method on solid biomasses. In this study the seed oil was also extracted from the seeds and analyzed. The solid byproducts of mechanical extraction, cake and meal, has been analyzed as solid biomasses. Some evaluations are proposed about the opportunity of an industrial recovery of oil.

The research has been developed by the Biomass Lab of the Università Politecnica delle Marche and it is part of a larger project of collecting data on the chemical characteristics of the principal solid biomasses of the Mediterranean Area. This research can represent a useful document for developing standards on these materials and to give suggestions for energetic and industrial chains, based on the recovery of residues coming from the tomato treatment.

2. Materials and methods

2.1. Short introduction

The tomato sauce production processes are different depending on the type of sauce to be produced. A schematic representation of tomato paste manufacturing process is

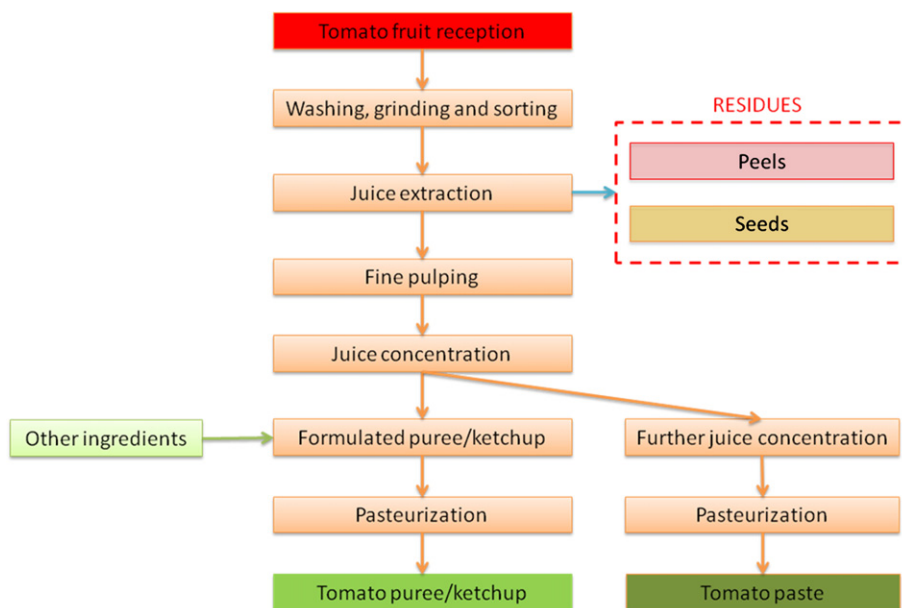


Fig. 1 – Schematic representation of tomato paste manufacturing process.



Fig. 2 – Separation of components left over from tomato sauce production process (from left to right: mixed residues in water; peels; seeds).

reported in Fig. 1. The main byproducts of the tomato paste manufacturing industry are represented by peels and seeds.

2.2. Sampling, processing and physical-chemical characterization of tomato residues

To realize this research, different types of products were collected. 32 samples of wet and dry residues deriving from tomato paste production process, that means a mix of peels and seeds, were taken from three important Italian food industries, located respectively at Ferrara (44°21'13"N, 12°10'18"E), Cuneo (44°25'15"N, 7°32'43"E) and Salerno (40°46'44"N, 14°45'02"E). Each sample refers to a single truck of residues. In particular 12 wet samples were collected at Ferrara, 10 wet samples at Cuneo and 10 dry samples at Salerno, all them related to July and August 2010 production.

The original 32 tomato residue samples were analyzed and then separated into 32 peel samples and 32 seed samples.

The different parts of the tomato residues (peels and seeds) were separated by sedimentation in water. Most of the seeds settle on the bottom while the peels remain afloat on the surface. Both components were oven dried (MPM M 120-VF and 400-VF drying oven models) and then, the seeds still trapped by the peels, were separated using a standard sieve (Retsch, Test Sieves, dimensions 400 mm × 65 mm, 1.40 mm mesh diameter) as reported in Fig. 2.

Further 6 tomato seed samples (mix of unknown variety), 4 tomato seed oil cake samples, obtained from mechanical extraction process, and 10 meal samples, produced by a chemical extraction plant, were collected in September 2010 from a company located close to Genova (44°31'04"N, 8°52'33"E).

Moreover, 6 tomato seed oil samples and further 6 oil cake samples were also produced in the Biomass Lab by means of mechanical extraction. Tests were realized on 5 kg seed samples. For this process a continuous press (2.27 kW power) produced by Bracco Company Ltd., with a capacity of 15 kg h⁻¹ seeds, was used.

All samples analyzed by the Biomass Lab for their physical-chemical characterization are summarized in Table 1.

Every sample was prepared following the UNI EN 14780:2011 Standard and then analyzed following the scheme shown in Fig. 3.

All solid products coming from the separation of the residues of tomato sauce manufacturing industry and from the pressing of tomato seeds were analyzed to find their physical-

chemical characteristics. In detail, moisture content, net heating value (NHV), lower heating value (LHV), higher heating value (HHV) and ash content were determined. A series of chemical elements was also determined. The analyses have always followed the CEN standards regarding solid biomass for energy use (Table 2).

To evaluate the suitability degree of the analyzed materials to be used for energy production, in this research a comparison with wood chips values found in literature was made [22].

Afterwards, the oil content was determined in 10 tomato seed samples to find the potential quantity that may be extracted and to calculate the yield of the mechanical extraction, that is the ratio between the quantity of the extracted crude oil and the quantity of processed seeds (on anhydrous basis).

Finally, to get some information about the characteristics of the mechanically extracted tomato seed oil, its fatty acid composition was determined by the gas chromatographic method.

2.3. Statistical analysis

Results were statistically evaluated with the Tukey–Kramer test at the 0.05 level of significance using the JUMP® 7.0.1 (SAS) software.

3. Results and discussion

3.1. Physical-chemical characterization

The results, reported in Table 3, show significant differences between the residues of the tomato industry and its components. The ash content of peels and seeds is similar and it tends to concentrate significantly in cake and meal parts. The net heating value is affected by moisture, so it is very low in

Table 1 – Samples analyzed.

Biomass	Nr samples
Tomato residues	32
Peels	32
Seeds	38
Tomato seed oil cake	10
Extraction meals	10

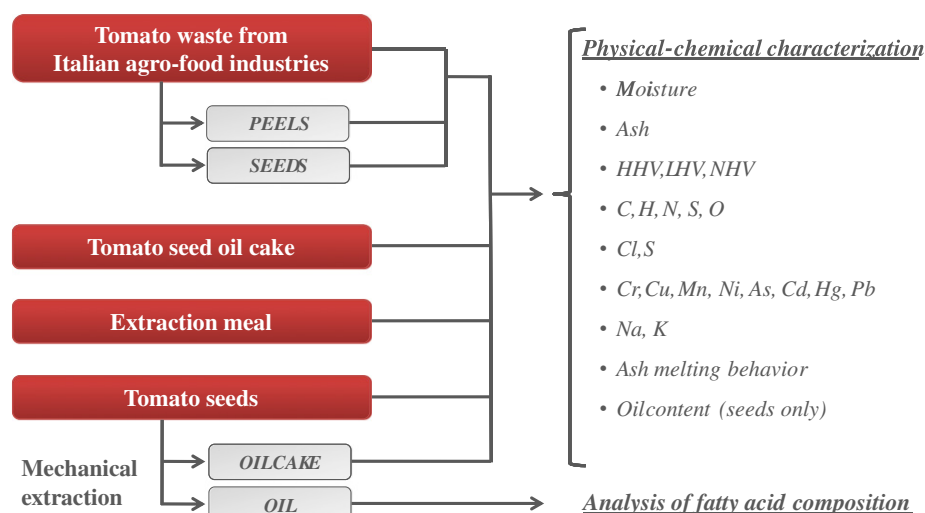


Fig. 3 – Scheme of analyses carried out on samples of biomass left over from the tomato industry.

the original product (wet residue) and assumes the highest values in peels, seeds and cake, as consequence also of their oil content. Wet residue thus needs some pretreatment like, for example, torrefaction before an energy application.

Regarding the chemical composition, nitrogen and sulfur are elevated in seeds and as a consequence of oil extraction process these elements are concentrated in cake and meal. The chlorine content is higher in separate components

Table 2 – Physical–chemical characterization of biomasses (residues of the production process of tomato puree, tomato skins, tomato seeds, tomato seed oil,^a oil cake, extraction meal) using standard methods.

Parameter	Instruments	Analytical method
Sample preparation	Laboratory mill IKA mod. A11 Basic	UNI EN 14780:2011
Moisture	Oven MPM Instruments s.r.l. series PID System, type M-VF	UNI EN 14774:2009
Ash	Muffle furnace mod. ZA 3.9 kW, $T_{\max} = 1100^{\circ}\text{C}$	UNI EN 14775:2010
HHV, LHV, NHV	Calorimeter IKA mod. C2000 Basic; CHNS/O Analyzer Perkin Elmer 2400 series II	UNI EN 14918:2010
C, H, N, S, O	CHNS/O Analyzer Perkin Elmer 2400 series II	UNI EN 15104:2011
Cl, S	Calorimeter IKA mod. C2000 Basic; Optical Emission Spectrometer Perkin Elemer mod. Optima 2100 DV	UNI EN 15289:2011
Cr, Cu, Mn, Ni, As, Cd, Hg, Pb	Microwave Reaction System Anton Paar mod. Multiwave 3000; Optical Emission Spectrometer Perkin Elemer mod. Optima 2100 DV	UNI EN 15297:2011
Na, K	Microwave Reaction System Anton Paar mod. Multiwave 3000; Optical Emission Spectrometer Perkin Elemer mod. Optima 2100 DV	UNI EN 15290:2011
Determination of ash melting behavior	Muffle furnace mod. ZA 3.9 kW, $T_{\max} = 1100^{\circ}\text{C}$; Ash melting behavior Analyzer SyLab IF 2000F	UNI CEN/TS 15370-1:2006
Analysis of fatty acid composition ^a	Multiposition heater for 500 ml flasks, Falc BE 4; SHIMADZU GC 2010 Gas Chromatograph, with a Stabnilwax type column (Restek), on-column injector and FID; external standard Supelco™ 37 Component FAME Mix	UNI EN ISO 5509:2001 UNI EN ISO 5508:1998
Determination of oil content ^b	Oven series PID System type M-VF; Laboratory mill IKA mod. A11 Basic; Soxhlet extractor 250 ml; Extraction time: 24 h; n-Hexane Panreac; Rotary vacuum evaporation Laborota 4000, Heidolph Instruments	ISO 659:2009

^a Analysis of fatty acids composition only performed on tomato seed oil from mechanical extraction.

^b Analysis performed on tomato seeds only.

Table 3 – Results of the characterization analysis of the tomato residues, its individual components and the oil cake obtained from the mechanical extraction of the tomato seed oil, compared with beech chips values found in literature.

Parameter	Peel	Seed	Cake	Meal	Dry residues	Wet residues	Beech chips ^a
Moisture (a.r. ^b) % ^c	5.4 c	5.4 c	3.7 d	3.0 d	7.2 b	73.1 a	10.2
Ash (d.m. ^d) %	3.8 bc	4.2 b	5.1 a	5.6 a	3.7 bc	3.3 c	1.0
HHV (d.m.) MJ kg ⁻¹	23.6 bc	24.5 a	23.0 c	20.3 d	22.9 c	24.0 ab	19.1
LHV (d.m.) MJ kg ⁻¹	21.9 bc	22.7 a	21.4 c	18.8 d	21.3 c	22.3 ab	17.8
NHV (d.m.) MJ kg ⁻¹	20.6 a	20.8 a	20.5 a	16.6 c	19.6 b	4.2 d	15.8
C (d.m.) %	56.8 a	57.3 a	52.5 b	49.3 c	55.0 a	56.0 a	48.8
H (d.m.) %	8.1 a	8.5 a	7.6 b	7.1 c	8.0 ab	8.3 a	6.0
O (d.m.) %	28.8 bc	25.0 c	29.2 ab	31.0 a	31.5 a	29.1 ab	44.5
N (d.m.) %	2.4 e	4.9 c	5.6 b	6.7 a	2.5 e	3.2 d	0.17
Cl (d.m.) %	0.17 ab	0.10 bc	0.24 a	0.11 bc	0.08 c	0.06 c	0.005
S (d.m.) %	0.07 d	0.20 b	0.28 a	0.30 a	0.16 bc	0.12 c	0.02
Cr (d.m.) mg kg ⁻¹	<1	<1	1.8	1.9	<1	<1	<1
Cu (d.m.) mg kg ⁻¹	11.6 e	17.3 c	22.5 b	27.3 a	16.2 cd	13.6 de	1.7
Mn (d.m.) mg kg ⁻¹	15.5 e	50.7 c	56.1 b	65.8 a	28.1 d	24.2 d	51.0
Ni (d.m.) mg kg ⁻¹	1.5 b	1.5 b	1.8 b	3.8 a	1.9 b	2.7 ab	1.0
As (d.m.) mg kg ⁻¹	<1	<1	<1	<1	<1	<1	<1
Cd (d.m.) mg kg ⁻¹	<1	<1	<1	<1	<1	<1	<1
Hg (d.m.) mg kg ⁻¹	<1	<1	<1	<1	<1	<1	<1
Pb (d.m.) mg kg ⁻¹	2.1 ab	2.2 ab	1.0 b	1.2 ab	4.0 a	3.4 ab	5.2
Na (d.m.) mg kg ⁻¹	189.6 a	44.5 c	45.4 c	52.2 c	85.5 b	67.8 bc	13.0
K (d.m.) mg kg ⁻¹	15 335 a	5986 c	6388 c	8306 c	11 291 b	9536 bc	1173

Values in the same row followed by different letters are significant at LSD 0.05.

a Values reported in Phyllis database related to beech chips [22].

b a.r. means as received, parameter analyzed in the samples as received by the analyst.

c The percentage is a mass fraction.

d d.m. means dry matter, value expressed on dry matter basis.

compared to the original residues. This is probably due to the chlorine in the water used for the separation treatment.

However, the concentrations of these three elements are much higher in all the residues with respect to the woody reference biomass.

Regarding heavy metals, a presence of copper and manganese in variable quantities can be noticed in the different biomasses. However, the concentrations of these elements are similar to those present in the reference biomass. The remaining heavy metals concentrations are very low. Finally, sodium and potassium are mainly present in the peels.

3.2. Tomato seed oil content and mechanical pressing yield

The measures of oil content, conducted in 10 different tomato seed samples, show average results ranging from 19.5% to 25.7% (mean value 22.3%, standard deviation 2.0%) on dry weight

basis. The crude oil, obtained by mechanical extraction in laboratory, had a yield over 12.0% on dry weight basis. The press thus extracts up to 60% of the total oil contained in the seeds.

3.3. Fatty acid composition

The fatty acid composition found by the gas chromatographic analysis is reported in Table 4 and shows an unsaturated fatty acid mass fraction > 75%, especially linoleic acid. The results are similar to those obtained by other authors [3].

4. Conclusions

In general, dry residues of tomato processing industry are suitable as solid biofuel for energy purposes. However, the high nitrogen content may cause serious environmental problems and chlorine and sulfur can promote corrosion processes in combustion systems. For these reasons it is preferable to use these biofuels in large size power plants where these issues are better managed. The separation of tomato residues determines an improvement and standardization of energy content of the various materials. However, this operation makes sense in case of production and exploitation of oil from tomato seeds. In fact, separation does not solve the problems related to the presence of chlorine and nitrogen, although these elements are greatly reduced in tomato peels. In conclusion it would seem desirable to use tomato peels for combustion and seeds for the production of vegetable oil.

Table 4 – Results of fatty acid composition analysis of tomato seed oil obtained through mechanical extraction. Values express the mass fractions on dry bases.

Fatty acid composition	%
Palmitic acid C16:0	14
Stearic acid C18:0	5
Oleic acid C18:1	21
Linoleic acid C18:2	57
Linolenic acid C18:3	1
Other	2

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